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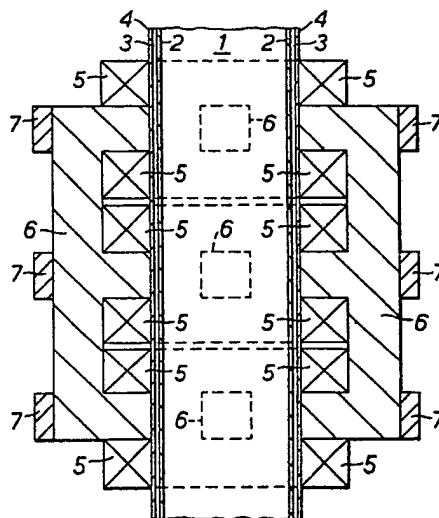
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54 Improvements in or relating to the continuous casting of steel.

57 Apparatus for continuously downwardly casting steel, including a continuous casting mould (1) and electromagnetic stirring means located about the metal strand path, the electromagnetic stirring means comprising a set of electromagnetic coils (5) disposed about the strand, the set of coils being connected to two separate power sources by means of two separate sets of connections such that one power supply and set of connections activates the set of coils to provide a rotational field force upon the strand, and the other power supply and set of connections activates the set of coils to provide an axial field force upon the strand.



IMPROVEMENTS IN OR RELATING TO THE
CONTINUOUS CASTING OF STEEL

This invention relates to the continuous casting of steel, and more particularly to electromagnetic stirring of the steel while still-molten and/or as it solidifies after pouring into a mould.

5 It has been found desirable to provide such stirring to many grades of cast steel for a number of reasons perhaps the chief of which in general is to achieve homogeneity of at least the major portion of the cross-section of the steel strand, and to remove non-metallic inclusions and included gases.

10 It has been proposed to provide helical stirring movement of the molten steel in continuous casting such an arrangement has useful application, and its value can be exemplified by the continuous casting of aluminium treated steel. Two noteworthy problems in the casting of such steel are the need to avoid
15 retaining inclusions of alumina in the steel as it is cast, and the need to ensure an outer surface layer around the strand free from included gas and entrapped slag. Previously proposed arrangements for horizontal, rotational stirring of the steel
20 suffer from the disadvantages, specially in the context of the above mentioned aluminium treated steel, that inclusions tend to be trapped and retained below the surface of the steel by rotating stirring action. In addition, with the commonly used

moulds of rectangular plan form, the rotational movement of stirring tends to create turbulence and/or standing waves at the mould corners which severely hinders the removal of inclusions and produces undesirable surface ripples on the strand surface. It is also desirable with this form of stirring to ensure that the stirring force penetrates to the central portions of the steel for adequate stirring throughout, which imposes restrictions on power supply frequencies.

Helical stirring can also, for example, have advantage in the casting of alloys with long solidification ranges, for example high carbon steels typically with carbon content ranging from 0.5 to 1.5%, where it would arrest the columnar crystal growth giving a central equiaxed structure with reduced mini-ingotism, bridging, central segregation of alloying elements and allow for a higher casting temperature without its pronounced deleterious effects.

It is an object of the present invention to provide an improved electromagnetic stirring arrangement for use in the continuous casting of steel.

According to the present invention there is provided apparatus for continuously downwardly casting steel, including a continuous casting mould and electromagnetic stirring means located about the metal strand path, the electromagnetic stirring means comprising a set of electromagnetic coils disposed about the strand, the set of coils being connected to two separate power sources by means of two separate sets of connections such that one power supply and set of connections activates the set of coils to provide a

rotational field force upon the strand, and the other power supply and set of connections activates the set of coils to provide an axial field force upon the strand.

5 The electromagnetic stirring means may be arranged about the strand within and/or below the casting mould.

By means of the invention it is possible by appropriate activation of the two power sources to provide an overall helical field force of adjustable helix angle to the strand.

10 The present invention overcomes potential disadvantages of previous proposals for helical stirring which suggested, for example, a skewed arrangement of coils which could be in some circumstances difficult to accommodate about a continuous casting mould and could in some circumstances give only a limited helix angle variation. Again a further previous proposal was for fixed
15 inductors about a continuous casting mould. Although in this arrangement the disposition of the inductors would not usually create any serious problem, the helix angles produced were found not always to be conducive to the best metallurgical effects upon the cast material.

20 The two power sources may be arranged with advantage to operate at different frequencies.

In order that the invention may be more readily understood one embodiment thereof will now be described by way of example with reference to the accompanying drawings in which:-

25 FIG. 1 is a diagrammatic sectional side elevation of the physical arrangement of coils connected for the arrangement of the present invention;

FIG. 2 is a diagrammatic plan in section of the arrangement shown in FIG. 1;

FIG. 3 is a circuit diagram for the axial field force supply system;

5 FIG. 4 is a circuit diagram of the rotational field force supply system; and

FIG. 5 is a circuit diagram of the combined axial and rotational systems;

Referring firstly to Figures 1 & 2 it is to be seen that a
10 continuous casting mould 1 is provided in the usual way with a copper mould wall 2 and is surrounded by a cooling water annulus 3 and an outer jacket wall 4 of austenitic steel. A plurality of coils 5 are located along each side of the mould and are mounted on main iron circuits 6 which are linked with secondary
15 iron circuits 7, necessary to allow for rotating magnetic flux.

It is to be noted that below mould stirring could be achieved with a similar arrangement of coils provided these were suitably protected from the hot strand by means of a larger clearance therefrom and appropriate heat shield in place of the mould wall 2.

20 Referring now to Figure 3, it is to be noted that each side of the mould is provided with a linear magnetic inductor 8 comprising the coils 5 and iron circuits 6 and 7 designed to produce an upward magnetic field. Each inductor is fed from a polyphase electrical supply 9, typically at low frequency. The
25 inductor coils are connected in star, adjacent inductors being connected anti-phase, thus producing within the mould a magnetic field with strong radial and tangential components. Adjustment

of the frequency and current produced by the axial supply allows the axial body forces in the material in the mould to be adjusted, resulting in axial movement of the molten material.

Referring now to Figure 4, it will be seen that a further
5 and separate polyphase supply 10 is connected to the star points 11 of the inductors 8 in correct phase rotation. The supply will induce a rotating field system about the vertical axis of the mould. Adjustment of the frequency and current produced by the rotary supply allows the rotational body forces in the material
10 in the mould to be adjusted resulting in rotational movement of the molten material.

As can be seen from Figure 5 a combination of the two supply arrangements of Figure 3 and 4 will result in a combination of axial and rotational body forces in the material in the mould
15 thereby resulting in helical movement of the material within the mould. The hydraulic conditions within the mould require a disproportionately large effort to move materials in an axial direction compared with the effort required to rotate them. From laboratory measurements it is thought that to obtain a helix angle
20 of 45° the ratio of axial to rotational forces may be of the order of 10:1 or even higher, which ratio can readily be obtained by means of the arrangement of the present invention, but would be difficult to obtain by means of a physically helically displaced array of inductors around the mould.

25 Advantageously, differing frequencies for the rotational supply and the axial supply are provided so that the RMS value of current in each coil is approximately the same. Should the

frequency of both the rotational supply and the axial supply be the same, the RMS value of current in each coil will in use vary so that there is risk of overheating the coils and at the same time under-utilising the coils.

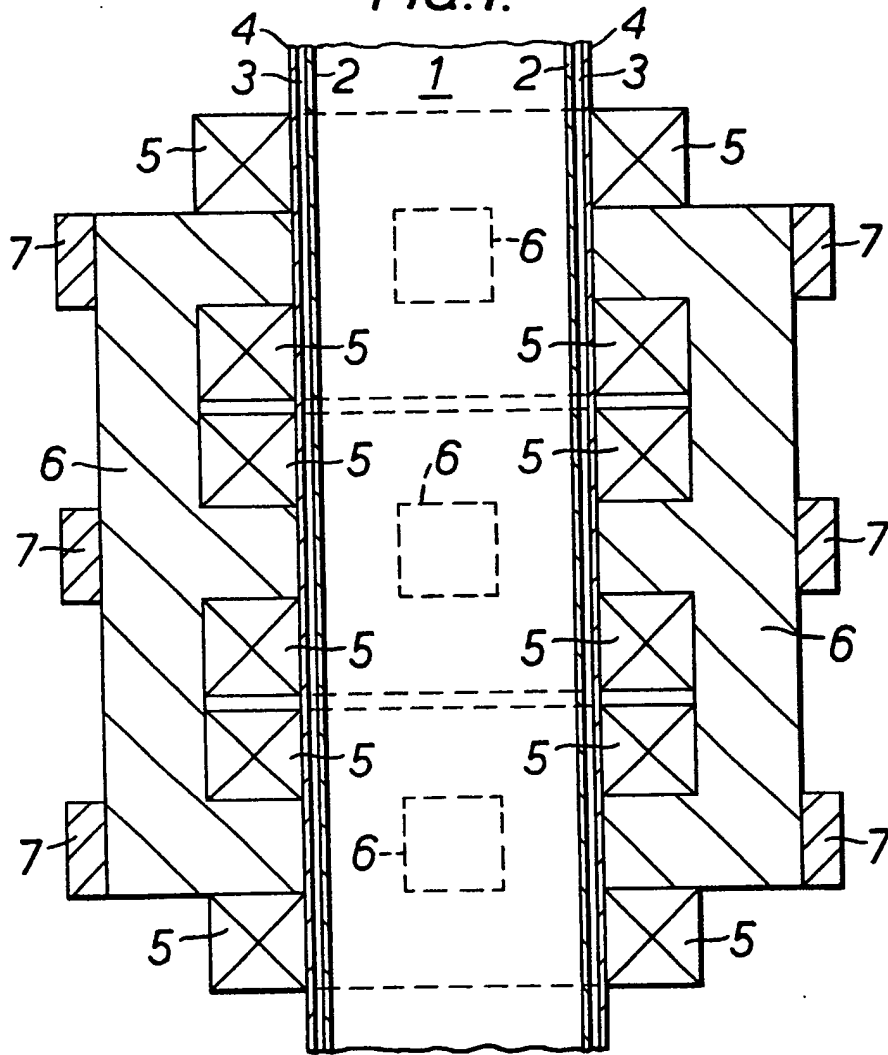
- 5 In one example, the calculated RMS Flux Density at the mould surface is, with respect to axial mode stirring, 0.19 Tesla with a travelling wave velocity of 3m/sec and an electrical input of 30 KVA; and is with respect to rotary mode stirring 0.09 Tesla with a frequency of 5 Hertz and an electrical input of 20 KVA. In this
- 10 example the mould has a copper inner jacket 8 mm thick, an austenitic steel outer jacket 8 mm thick, and a 4 mm water gap. The stirred length along the strand is approximately 650 mm and the mould section 150 mm square.

CLAIMS

1. Apparatus for continuously downwardly casting steel, including a continuous casting mould and electromagnetic stirring means located about the metal strand path, the electromagnetic stirring means comprising a set of electromagnetic coils disposed about the strand, the set of coils being connected to two separate power sources by means of two separate sets of connections such that one power supply and set of connections activates the set of coils to provide a rotational field force upon the strand, and the other power supply and set of connections activates the set of coils to provide an axial field force upon the strand.
2. Apparatus as claimed in Claim 1 wherein the set of coils comprises a plurality of columns of coils disposed about the strand path, each column including a plurality of coils, coils being linked with iron circuits around the strand path and along the length of the strand path.
3. Apparatus as claimed in Claim 1 or 2 wherein the stirring means is disposed about the continuous casting mould.
4. Apparatus as claimed in Claim 1, 2 or 3 wherein the arrangement is such that the power supplied for the rotational field is at a different frequency to that supplied for the axial field.
5. Apparatus as claimed in any one of the preceding claims wherein the arrangement is such that the power supplied for the rotational field is less than that supplied for the axial field.

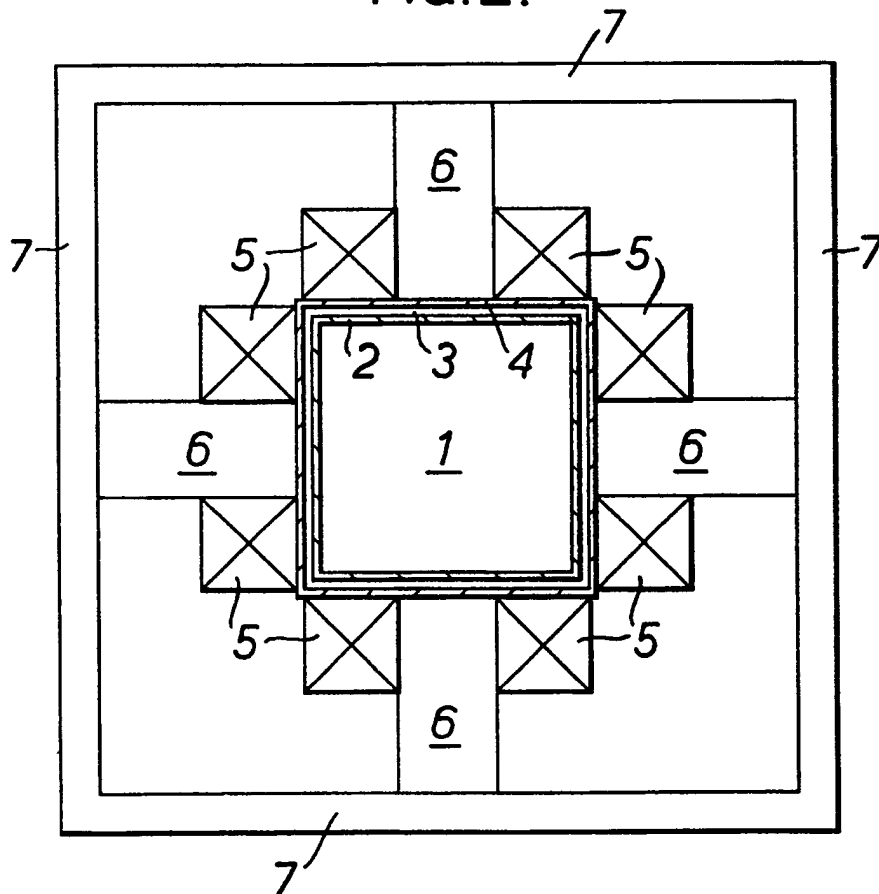
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FIG. 1.



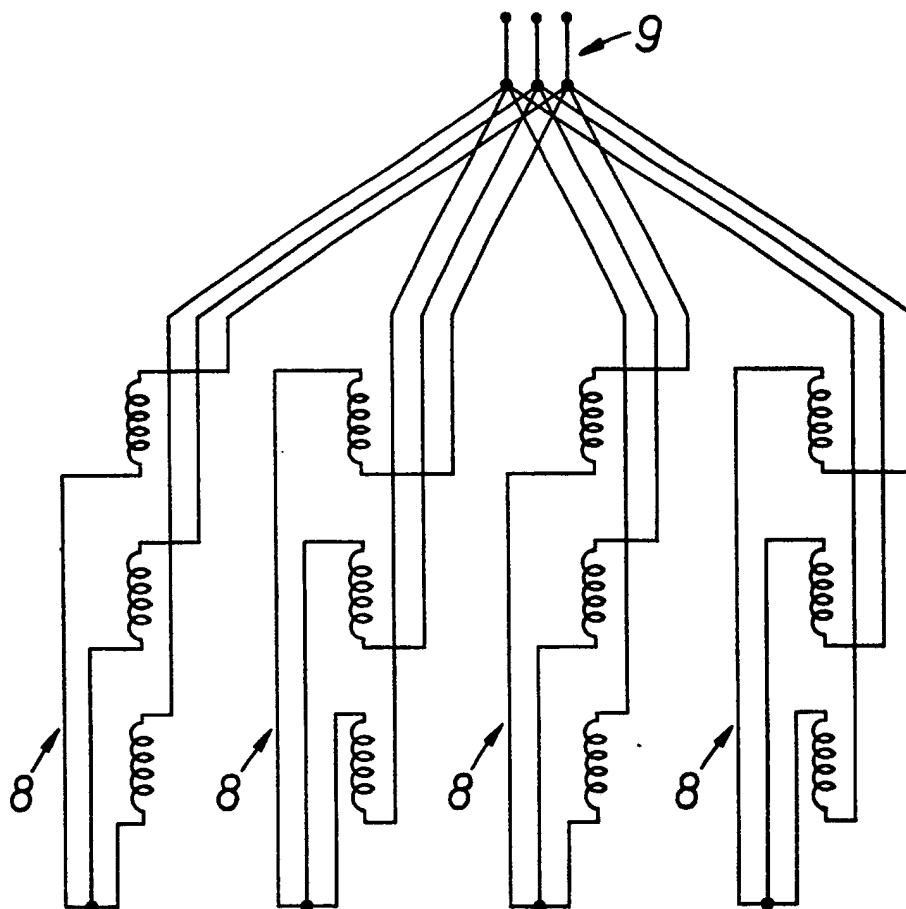
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FIG. 2.



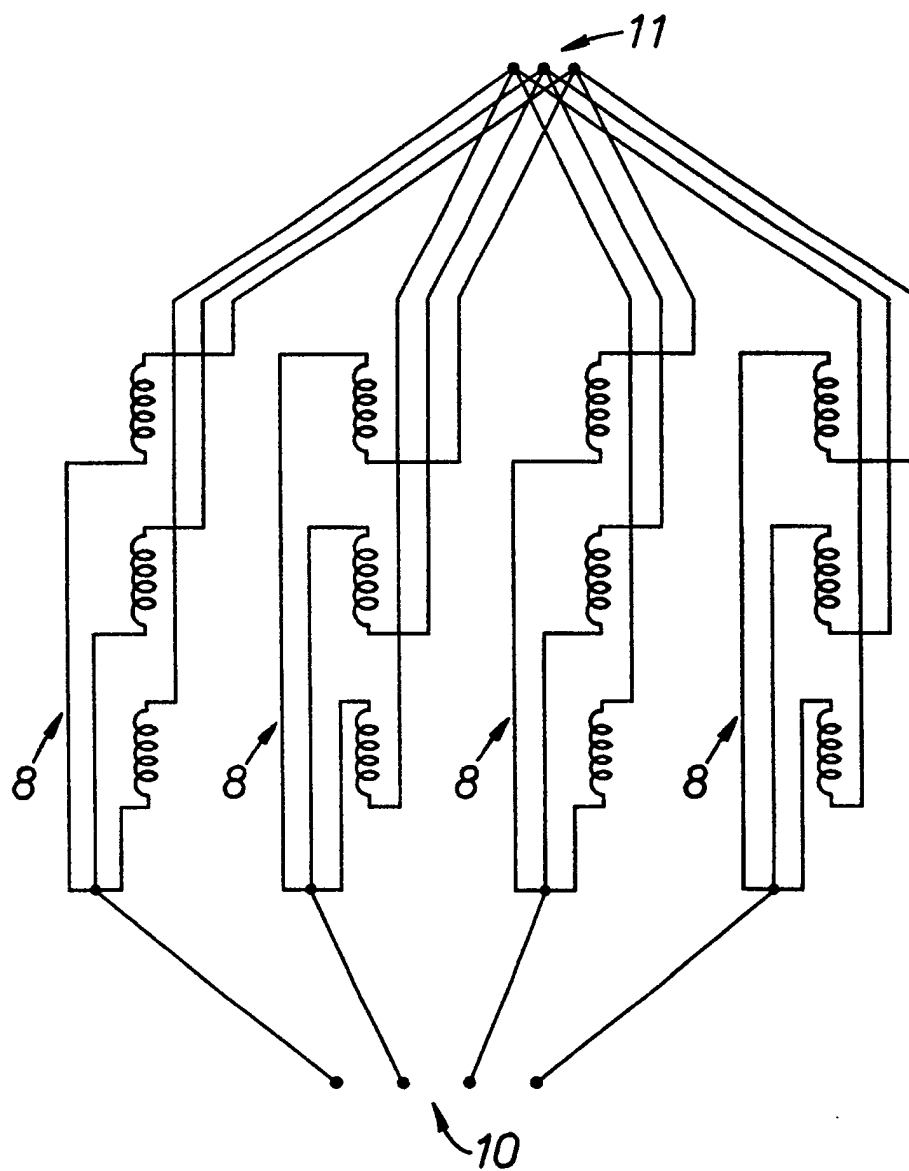
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FIG. 3.



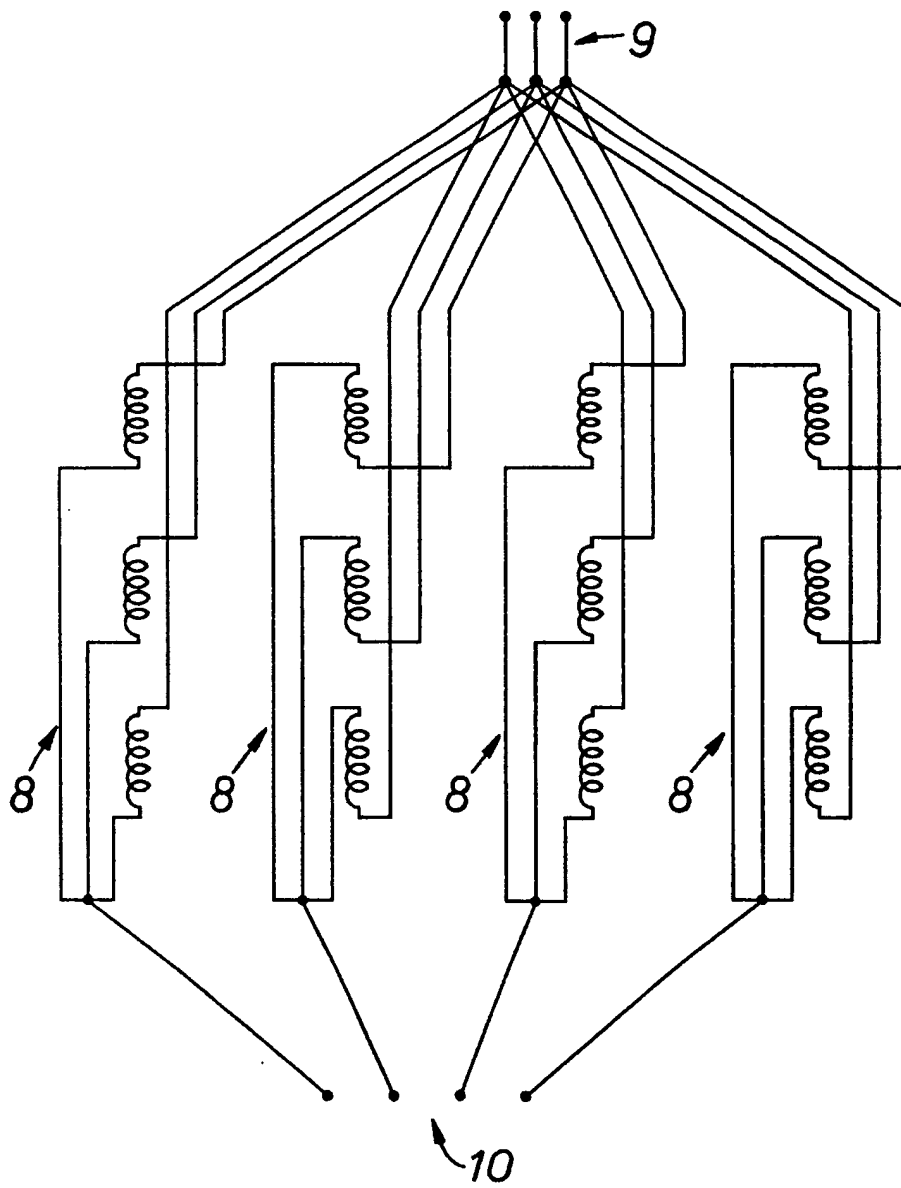
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FIG. 4.



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FIG. 5.





European Patent
Office

EUROPEAN SEARCH REPORT

0080326

Application number

EP 82 30 6122

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	DE-A-2 903 225 (CONCAST AG) * Claim 1 *	1	B 22 D 11/10 B 22 D 11/12 B 22 D 27/02
A	DE-U-7 801 279 (AEG-ELOTHERM) * Claims 1, 2 *	2	
A	US-A-3 995 678 (ZAVARAS et al.) * Claims 13, 19 *	1	
A	WO-A-8 001 999 (BRITISH STEEL CORP.) * Whole document *	1-4	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			B 22 D 11/00 B 22 D 27/00
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 21-01-1983	Examiner GOLDSCHMIDT G
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	